INVESTIGATIONS OF POWER AND POWER COSTS

BY

R. B. AMBROSE

ARMOUR INSTITUTE OF TECHNOLOGY

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ARMOUR INSTITUTE OF TECHNOLOGY

CHICAGO, ILLINOIS.

DEPARTMENT OF

MECHANICAL ENGINEERING.

Thesis.

212.03
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Subject - Investigations, with recommendations, of Power and Power Costs, in Plant No. 2, Falls Creek Sand and Stone Co.

Submitted by - R. B. Ambrose.

Date - May 10, 1921.

Class of - 1911

Department of - Mechanical Engineering.

Candidate for degree of - Mechanical Engineer.

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INVESTIGATIONS, WITH RECOMMENDATIONS, OF POWER AND POWER COSTS, IN PLANT NO. 2. FALLS CREEK SAND AND STONE CO., FALLS CREEK, PA.

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INVESTIGATIONS, WITH RECOMMENDATIONS, OF POWER AND POWER COSTS, IN PLANT NO. 2, FALLS CREEK SAND AND STONE CO., FALLS CREEK, PA.

THE PLANT.

The Falls Creek Sand and Stone Company's plant No. 2 was built for the manufacture of various kinds of sand for molding, plate glass polishing and sand blast purposes. It has a capacity of one thousand tons of crushed rock per day, and while it is not the purpose of this paper to discuss the various processes of sand manufacture, a brief outline of the passage of material through the mill will be pertinent to the subject.

Fig. 1 shows a general layout of this plant. A large quarry feeds the mill with rough sand stone, which is initialls broken up by shots of dynamite. A mixture of large and small stones and sand, thus broken, is loaded on to dumping cars and switched to the track adjacent to the initial crusher as shown in Fig. 1. The contents of the cars is dumped and falls by gravity into the initial crusher, which reduces all the stone to 6" or 8" in size, at a rate of one thousand tons per ten hours of continuous operation. The stone from this crusher is then lifted to the top of the mill by a bucket conveyor elevator, and discharged on a screen of heavy wood strips. This screen allows pieces of about 2" or smaller to fall through, and discharges all larger pieces into a large bin which feeds the secondary crusher. (See Fig. 1.)

All fine sand and pieces of stone, passing through the wood screen are conveyed by belt conveyor to the wet will. All other stone, which must go through the secondary crusher, is conveyed by another belt conveyor to the dry mill. Here it is further reduced in size by heavy rolls operating in the dry pans, and is then sent to the wet mill for final crushing and separating. The wet mill gives the final grinding and separating, while the dry mill supplements the crushers in reducing all stone to wet mill size.

After passing through the rolls of the wet pans, in the wet mill, the sand is lifted from the water in the settling basin by screw conveyors to the finished sand belt conveyor. This lifts the sand to the small tower for loading. (See Fig. 1.)

POWER EQUIPMENT.

The power equipment installed in this plant, for the purpose of generating power and of driving the various machine units of the mill, is listed below. Fig. 1 shows these various power units in their respective positions with the motor numbers where such are available. The 5 H.P. induction motor on viabrator screen, on account of its very small power consumption is not shown on Fig. 1, nor is it used in any subsequent calculations.

The equipment list follows:

1 - 19" x 22" Westinghouse, 3 cylinder gas engine

1 - Direct connected A.C. generator, 210 K.W. 220 Volts, 2 Phase.

1 - Belted A.C. generator, 220 Volts, 300 Amperes, 3 Phase.

1 - 125 H.P. Struther Wells, 2 cylinder, horizontal gas engine, driving secondary crusher, and elevator to dry mill.

1 - 65 H.P. Otto, 1 cylinder gas engine, driving large air compressor.

1 - 80 H.P. Du Bois, 2 cylinder tandem, gas engine, driving small air compressor and dry pans.

1 - 5 H.P. induction motor, small viabrator screen, dry mill.

1 - 10 H.P. induction motor, driving belt conveyor, from initial crusher elevator to wet mill. No. 2334659.

1 - 10 H.P. induction motor, driving belt conveyor, from dry mill to wet mill conveyor. No. 583791.

1 - 35 H.P. induction motor, driving bucket elevator from initial crusher. No. 2327395.

1 - 100 H.P. induction motor, driving initial crusher. No number.

1 - 40 H.P. induction motor, driving wet pan No. 1. No. 2317667.

1 - 40 H.P. induction motor, driving wet pan No. 2. No. 2317665.

1 - 15 H.P. induction motor, driving screw conveyor No. 1. No. 2338173.

1 - 15 H.P. induction motor, driving screw conveyor No. 2. No. 2200894.

1 - 10 H.P. induction motor, driving pebble elevator. No. 683785.

1 - 30 H.P. induction motor, driving belt conveyor for finished sand. No. 2327396.

1 - 75 H.P. induction motor, driving triplex plunger pump. No. 92415.

1 - 20 H.P. induction motor, driving centrifugal pump. No. 2285441

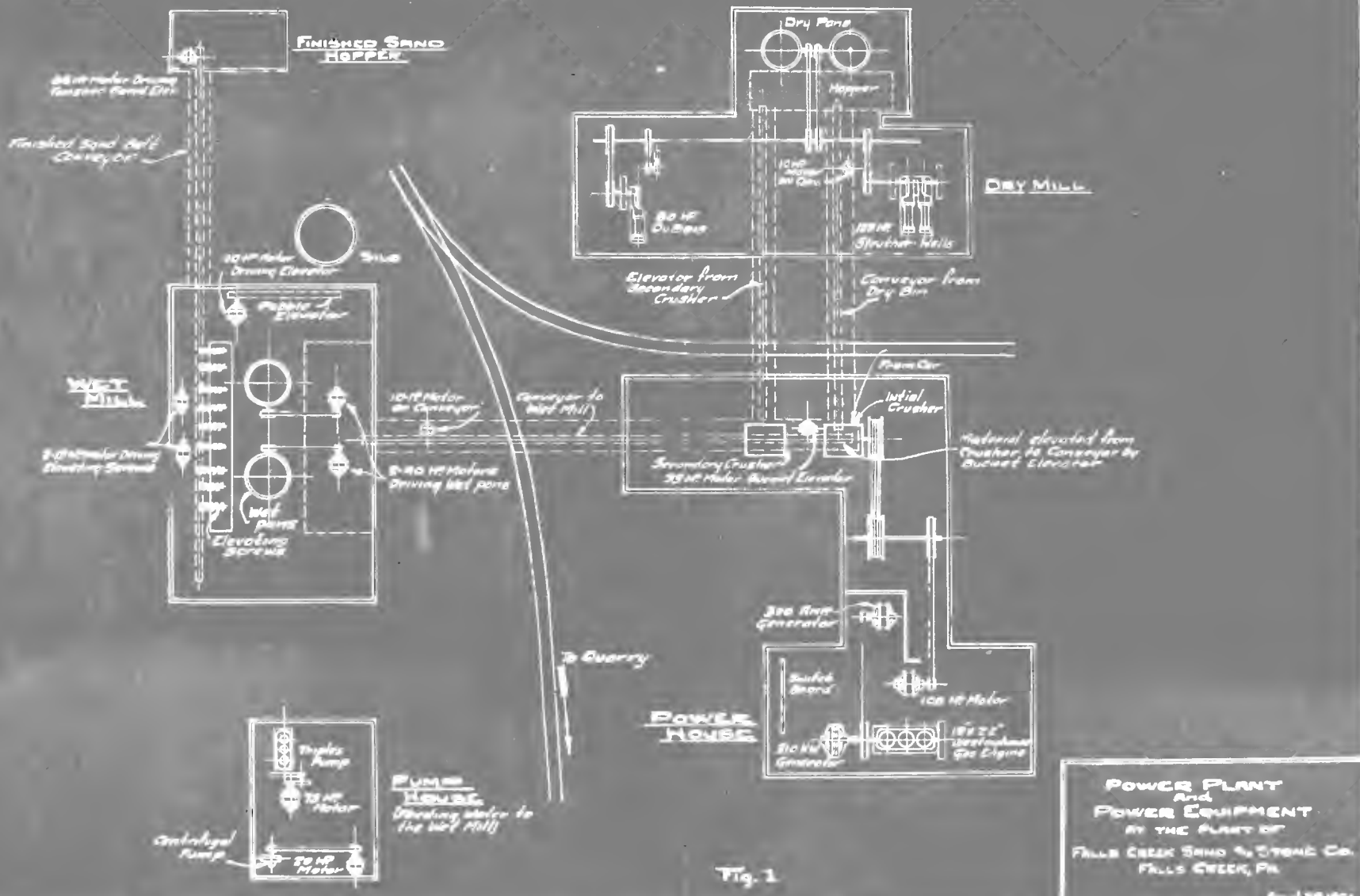

Fig. 1

Power Plant and Power Equipment at the Plant of Falls Creek Sand & Stone Co. Falls Creek, Pa.

April 29, 1921

TROUBLES REPORTED.

The main trouble that existed in this plant was the unreliability of power service. The plant was rated at 25000 tons of finished sand per month, and was producing only 8 to 10000 tons. The main generator heated badly, and the gas engine would slow down at times to such an extent, as to loose its grip on the load. Low voltage followed, and important motors about the plant would be kicked off the line. Break downs occured as a rule rather than the exception.

CONDITIONS FOUND.

The writer inspected this plant on Sept. 30, Oct. 1 and 2, 1920, and found a very low power factor and high generator temperature. To aggravate this trouble skilled engine operators and repairmen had been sadly lacking. Only two weeks before this visit had a change been made and a new master mechanic placed on the job. He seemed to be a hustler and a good mechanic, and had already begun to nurse the gas engine to greater efficiency and greater reliability.

This attention seemed to have given the engine a little more power, but the generator continued to get almost frying hot at times. This heating had been mistaken for generator overloading, and at some previous time, heroic measures had been adopted, and a second generator belted to the flywheel of the engine as shown in Fig. 1. The main generator was built for two phase four wire system. The two phase was changed to three phase before distribution. The second generator was of the three phase type, and was used to share the load of the main machine, although driven by the same engine. Obviously the two generators could not be syncronized, but were operated on separate circuits.

The writer made indicator tests of the gas engine to ascertain what maximum power might be expected from it. This was done by cutting out one igniter until the engine had slowed down sufficiently to open the governor full. The igniter was then cut in and the card taken. This was repeated for each cylinder. The mean effective presaures thus obtained when used with the running revolutions per minute of the engine gave a very close approximation to the maximum indicated horse power. The writer also carefully observed various phases of the plant operation during the three days and submitted the following report:

REPORT, Sept. 30, Oct. 1-2.

GAS ENGINE POWER:

The gas engine was found to be developing approximately 298 Indicated Horse Power, when the switch board showed an output of 150 K. W. 298 Indicated Horse Power is equivalent to about 268 Brake Horse Power, and this is equivalent to 200 K. W. needed to drive the generator when it shows the output of 150 K. W. This represents a generator efficiency, which in a good alternator should be 90% or better, of only 75%.

This engine if kept in good running condition will develop close to 230 K. W. With a generator efficiency of 90% or better, there would be available for work a maximum of 208 to 210 K. W. With a generator efficiency of 75%, as it is at present, there is available for work a maximum of 175 K. W., and the generator heats badly at this and much lower loads.

POWER FACTOR:

When the switch board showed an output of 150 K. W., one ammeter read 500 and the other read 525, while the voltage read 236. The sum of the ammeter reading (1025) multiplied by the voltage (236) and divided by 1000, equals 242 Kilo-volt-amperes, on this two phase syatem. The 150 K. W. divided by the 242 K. V. A. and multiplied by 100, equals 62% power factor. In other instances recorded during this test the power factor showed as low as 50%. In an alternating current system, where the power factor is low, there is a heavy current surging through the generator windings, serving no useful purpose and causing heating of the coils. In this particular case with a power factor of 50% to 60% a greater proportion of the current produces heat than produces work. This accounts for the low generator efficienoy and for its excessive heating.

Low power factor is caused by the current not being in step with the voltage, and in this particular case, with a heavy induction motor load the current lags behind the voltage. With an increase in power factor, this current is placed more nearly in step with the voltage, the generator efficiency will rise and up to 30 K. W. more may be available for work at the maximum load of the engine. And furthermore the generator will be able to carry this load with less heating than at present. Instead of the generator being over loaded it should be able to take care of all the power the engine can generate, and at the same time keep reasonably cool.

MOTOR ON ELEVATOR FROM INITIAL CRUSHER:

This motor is reported to have kicked off several timea when the voltage of the system becomes low. A test of this motor indicated that it was not over loaded, but that it carried a fairly good proportion of its rated capacity. Since this motor is pulling a vertical bucket elevator, its load and torque requirements are not relieved when the motor slows down. In an induction motor, if the voltage drops a little the speed drops a great deal more, which when combined with heavily loaded buckets of the elevator, causes a very appreciable drop in speed. The control of this motor has both a low voltage and over load release. Low voltage may cause the motor to trip directly through the low voltage release, or indirectly through the overload release by an abnormal drop in speed. The motor is not defective but its service demands that the voltage be kept at 220 or higher. This of course reflects back to the main engine and generator, and the remedy must be applied at this place.

REPORT, cont'd.

ENGINE RELIABILITY

"The reliability of the Westinghouse gas engine is dependent to a very great extent upon the skill and attention it receives from its operators. It seems that the present master mechanic is thoroughly capable in handling this end, and with one good engineer to assist him on each shift, there should be little trouble with engine shut downs. It is suggested in this respect that each engineer be required to thoroughly inspect all vital parts of the engine, including the igniters, and make necessary repairs, daily, during the four hours shut down out of twenty four. This engine should be treated much in the same way as an emergency engine in fire or similar service, except that it is not called on to work intermittently, but must work continuously."

"The efficiency of your plant depends on this engine, and in the absence of a spare unit, it is increasingly urgent that every care be taken to keep it in the pink of condition. The week part should be caught before it has a chance to cause a shut down, and this can be done only by frequent, thorough inspections."

"With the power factor improved the engine will take the same load easier, and will stand an additional load of 25 to 30 K. W. with out overheating. All of these things combined should go a long way toward the improvement of your power condition."

PROPOSED METHOD OF INCREASING POWER FACTOR:

"The cause of low power factor, as has been stated, is in this case the lagging of the current behind the voltage. A syncronous motor running light may be used to cause the current to lead the voltage. Such a motor in parallel with the induction load will neutralize either wholly or partially the lagging current, and cause it to be more nearly in step with the voltage."

"Since a syncronous motor of large size would be an expensive proposition, it is proposed to remove the belt from the small auxilliary generator, and run this generator as a syncronous motor with no load. A loaded syncronous motor will not have a current leading the voltage to such an extent as the same motor running light. It is therefore proposed to run this motor with no load, so that its influence in correcting the power factor will be as great as possible. Its capacity is hardly large enough for complete correction even when running light, but it represents the cheapest and most logical thing to try, and will undoubtedly prove of sufficient value to keep in that form of operation."

"To operate this generator as a syncronous motor, it will be necessary to tie into the three phase panel of the large generator, through the main switch of the small generator panel, and attach syncronizing lights. An 8 to 10 horse power variable speed induction motor will be necessary to bring this motor up to speed." (NOTE. When it came to actually putting this syncronous motor into operation, an old squirrel cage type motor was found about the plant, and a suitable sized pulley placed on the shaft, so that its running speed was very near syncronous speed. It worked very successfully.)

REPORT, cont'd.

IN SUMMARY.

"The following comparison is emphasized:

PRESENT OPERATION

Engine capable of developing - - - - - - - - - - - - - 230 K.W.
Efficiency of generator, estimated - - - - - - - - - - - 75%
Power factor - 50% to 60%
Power available for motors - - - - - - - - - - - - - - 175 K.W.
Generator heats.

PROPOSED OPERATION

Engine capable of developing - - - - - - - - - - - - - 230 K.W.
Efficiency of generator, estimated - - - - - - - - - - - 90%
Power factor, estimated - - - - - - - - - - - - - - - - 85% to 90%
Power available for motors - - - - - - - - - - - - - - 210 K.W.
Generator runs cool.

By R. B. Ambrose,
Carnegie Institute of Technology.

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MOTOR TESTS.

Since the power factor of an induction motor improves with increased loading, the writer again visited this plant on Oct. 15-16 for the purpose of testing the power input of each motor of list on page 2. It was desired to find out to what extent each motor was helping to lower the plant power factor, and to determine to what extent this factor might be improved by better loading.

A single indicating watt meter was used and connections were made as indicated in Fig. 2. The current coil of the meter was connected directly across the middle fuse, and the fuse withdrawn. With suitable size wire, and by hooking the ends in between the springs which held the knife fuse, it was possible to connect the meter and disconnect it without shutting down the motor. The voltage connections were placed across the fuse terminals as shown in Fig. 2, one permanently fastened to the middle terminal and the other touched first to the one and then the other of the remaining terminals. Two readings were thus obtained The algebraic sum of which represents the watts input.

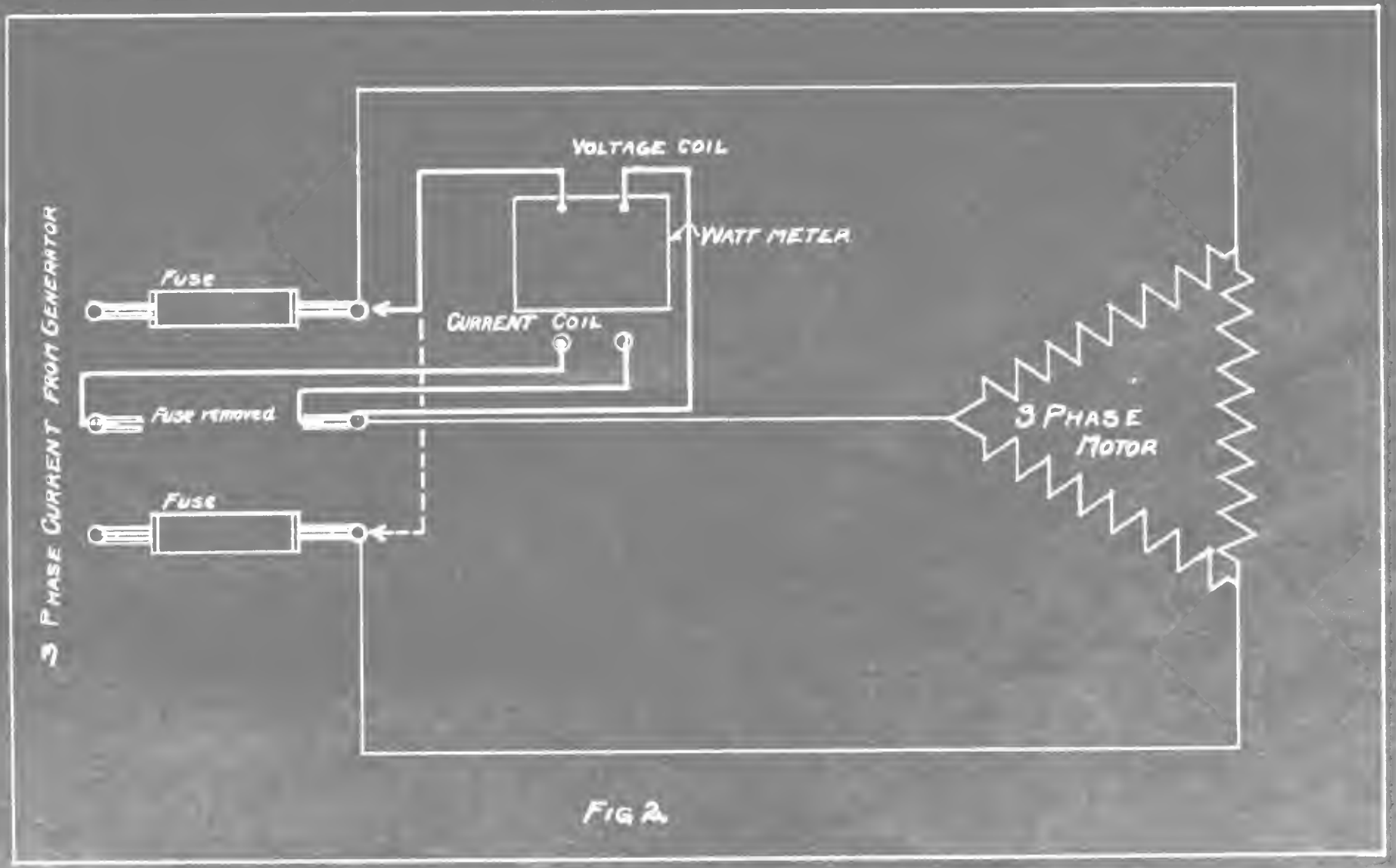
3 Phase Current from Generator
Voltage Coil
Watt Meter
Fuse
Current Coil
Fuse removed
Fuse
3 Phase Motor

Fig 2.

MOTOR TESTS, cont'd.

The power factor of each motor was calculated as follows:

$$\text{Power factor} = \cos \phi = \cos \tan^{-1}\left(\sqrt{3}\ \frac{P_2-P_1}{P_1+P_2}\right)$$

Where P_1 = watt meter reading with voltage connections at 1 and 3.

" P_2 = watt meter reading with voltage connections at 2 and 3. as indicated in Fig. 2.

In the following report, which also includes table No. 1, are shown the results of these tests and calculations.

REPORT, Oct. 15-16.

"The attached table shows the results of the tests made on your induction motors on Oct. 15-16. A careful study has been made of each individual motor, and this table shows the calculated results of the K. W. demand, Power Factor, and percent of rated load for each motor, for both light and loaded condition. The columns under "RUNNING LIGHT" on this table refer to the motor connected to the machine which it is driving, but with no sand going through. The "RUNNING LOADED" columns refer to the motor pulling the machine with a maximum amount of sand obtainable at this time. Motor No. 5 on the centrifugal pump has no running light data, because it was connected to a constant load which could not be varied without removing belt or losing its water. Motor No. 6 on initial crusher has no name plate, and the serial number, rated K. W. and percent rated capacity could not be obtained. Motors No. 11-12 could not be loaded on the Saturday afternoon that these tests were made, and there is therefore no loaded data for these."

"The purpose of these tests was to determine the loading of each motor, and the power factor in each case, so that an intellegent analysis could be made as to the extent that each motor was influencing the low plant power factor, and to furnish a guide to future motor loading."

"A discussion of the results of these tests follows:"

"When running light, it will be noticed from the table, that all motors except the Pan Motors and the Triplex Pump Motor were running at very low percent of rated load and at very low power factor. The load could not be relieved to any great extent on the Pan and Pump Motors, hence the better power factor and better percent rated load."

"Under loaded conditions Motors No. 1-2-3-7, are decidedly under loaded, and it is quite probable that Nos. 11 and 12 are also much under loaded, although no load was obtainable on these at the time this test was made."

"Further inspection of the table readily shows that high power factor accompanies fully loaded motors and that low power factor accompanies lightly loaded motors. Since high power factor is necessary for efficient operation and cool running of the generator, it is very important that all motors be given proper load, and every effort made to keep them well loaded while in operation."

"A suggested re-grouping of these motors is given at the bottom of the table. An inspection of the power factors of the motors loaded will show the highest to be .89 for the pan motors, and they also have the highest percent rated capacity (92%). It would not be advisable to place any more load on these motors, but considerable improvement can be made by operating both screws by one 15 H.P. motor, and making other changes as indicated below."

REPORT, Oct. 15-16, cont'd.

"It is hardly fair to expect more than 89% power factor on any of the motors and the small ones will do well to get much over 80%. If all motors were well loaded, and there was no fluctuation in the load, we could expect from 80% to 85% plant power factor. We must, however contend with a fluctuating load, sometimes to a very great extent, and our power factor suffers accordingly. Regrouping of some of the motors as suggested below, in combination with the use of a syncronous motor as suggested in a previous report will go a long way toward improving the power conditions."

"The table showing results of the motor tests, follows:

TABLE NO. 1.

TEST OF INDIVIDUAL MOTORS,
FALLS CREEK SAND AND STONE CO., FALLS CREEK, PA.

			RUNNING LIGHT			RUNNING LOADED		
		RATED K.W.	ACTUAL INPUT K.W.	POWER FACTOR	%RATE LOAD	ACTUAL INPUT K.W.	POWER FACTOR	%RATE LOAD
1. Screw motor No.	2338173	14.3	2.8	.46	19.6	4.4	.53	30.0
2. Screw motor No.	2200894	14.3	3.0	.41	21.0	4.8	.57	33.0
3. Belt conveyor, finished sand,	2327396	26.0	3.0	.27	11.5	9.6	.55	37.0
4. Triplex pump,	92415	63.4	35.6	.75	56.0	41.6	.76	65.0
5. Centrifugal, pump,	2285441	17.8				12.4	.80	70.0
6. Initial crusher,			23.2	.54		46.0	.86	
7. Cross conveyor init. crusher,	2334659	9.25	2.36	.40	25.5	3.6	.56	39.0
8. Elevator, init. crusher,	2327395	26.5	3.00	.31	11.3	14.4	.70	54.5
9. Pan motor,	2317667	33.7	23.8	.89	70.6	31.0	.89	92.0
10. Pan motor,	2317665	33.7	27.0	.86	80.0	31.0	.89	92.0
11. Pebble elevator,	683785	8.72	1.78	.47	20.4			
12. Cross conveyor dry mill,	583791	8.72	1.4	.39	16.0			

"The following is a suggested method of re-grouping some of the above mentioned motors, to increase the power factor of the entire plant."

"No. 1 and No. 2 both driven by one 15 H.P. motor.
"No. 3 driven by 15 H.P. motor.
"No. 4 and No. 5 both driven by 75 H.P. motor.
"No. 7 and No. 12 both driven by one 10 H.P. motor.
"No. 8 elevator increased in width 50% and kept at same speed.

"This regrouping will give a surplus of two 10 H.P., one 20 H.P. and one 30 H.P. motors, which may be used for future expansion of power requirements. They should not, however be connected to system unless loaded to at least 75% of their rated capacity.

By R. B. Ambrose,
Carnegie Institute of Technology.

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REGROUPING OF MOTORS.

The motors were regrouped in accordance with the preceeding report with the exception of No. 7 and No. 12. It was found impracticable to operate both cross conveyors by means of one motor. These conveyors ran at right angles to each other, and it was not only difficult of application to one motor, but they were only accasionally operated together.

On Nov. 19-20 other tests were made to ascertain the effects of the regrouping, and on Nov. 29 the small generator, which had previously been belted to the main engine flywheel, was placed on the line as a syncronous motor running light.

The results of these tests are shown in the two reports following:

REPORT, Nov. 19-20.

"On Nov. 19-20 power tests were made on the 75 H.P. Triplex Pump motor No. 92415, the 15 H.P. Screw motor No. 2338173 and the Belt Conveyor motor, 15 H.P. No. 2200894, which motors had been regrouped according to recommendationa in report of Oct. 15-16."

"The 75 H.P. Pump motor No. 92415 now carries the additional load of the centrifugal pump, formerly carried by the 20 H.P. motor No. 2285441. The 15 H.P. motor No. 2200894 now carries the belt conveyor formerly carried by the 30 H.P. motor No. 2327396. The 15 H.P. Screw motor No. 2338173 now carries both screw conveyors, farmerly carried by this motor and the 15 H.P. motor No. 2200894."

"At the time of these tests, the motors were loaded as much as possible, and the following table gives ready comparison with previous tests shown in report of Oct. 15-16."

TABLE NO. 2.

	TESTS OF OCT. 15-16 LOADED			TESTS OF NOV. 19-20 LOADED		
	Input K.W.	Power Factor	%Rate Load	Input K.W.	Power Factor	%Rate Load
1. Triplex pump motor No. 92415	41.6	.76	65	56	.84	89
2. Screw motor No. 2338173	4.4	.53	30	8.8	.75	61.5
3. Belt conveyor motor No. 2327396	9.6	.55	37			
motor No. 2200894				9.4	.76	66

"This table indicates clearly the increase in power factor obtainable by loading the motors. However, in order to secure the advantage of this power factor, effective at the generator, these motors must be loaded continuously. Any motor or group of motors on the system, that drops back to no load condition, has just so much ill effect on the power factor. That this is just the condition existing in your plant is borne out by actual test. The above table shows substantial increase in power factor for individual motors, while observation of the switchboard during normal operation of the plant showed little or no improvement. Load fluctuation is the great difficulty with this method of power factor increase, and for this

REPORT, Nov. 19-20, cont'd.

reason, every attempt should be made to keep the motors loaded during their entire period of operation. If the load drops off they should be shut down."

By R. B. Ambrose,
Carnegie Institute of Technology.

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REPORT, Nov. 29, Dec. 3-4.

"In order to ascertain to what extent the small generator previously referred to, might be used as a syncronous motor for increasing the power factor, this generator was placed on the line as such syncronous motor on Nov. 29. It was brought into syncronism by means of a belted, squirrel cage induction motor and syncronizing lights. The initial crusher motor was then started and run without load, under which condition its power factor, according to Table No. 1 should be about 54%. By adjustment of the exciting current of the syncronous motor, a very decided drop in amperes was noticed on the switch board. An adjustment was finally reached when the kilo-volt-amperes were the same as the reading of the watt meter, indicating a power factor of 100%."

"On Dec. 3-4, tests were again made, with all motors in the plant operating normally and the syncronous motor on the line. The results of such tests, including the one made on Nov. 29, in comparison with previous data obtained under similar conditions without the syncronous motor," are shown below:"

TABLE NO. 3.

BEFORE USING THE SYNCRONOUS MOTOR.

Item No.	Voltage	Amps.	Amps.	Kilo-volt amps.	Kilo-watts	Power Factor.
1.	235	450	475	217.3	100	.46
2.	230	250	275	120.8	60	.49
3.	235	510	550	249.1	155	.62
4.	230	100	115	49.4	25	.50
	AFTER USING THE SYNCRONOUS MOTOR.					
5.	232	260	290	127.6	85	.67
6.	228	400	425	188.0	140	.74
7.	224	185	210	88.5	70	.80
8.	220	100	125	49.5	49.5	1.00

Sample calculation item No. 1.

Voltage taken from indicating voltmeter, = 235.
Amperes taken from two indicating ammeters, two phase current, = 450 and 475

$$\text{Kilo-volt-amperes} = \frac{235 \times (450 \text{ plus } 475)}{1000} = 217.3$$

Kilo-watts taken from indicating watt meter = 100

$$\text{Power factor} = \frac{100}{217.3} = .46$$

REPORT, NOV. 29, DEC. 3-4. cont'd.

"These figures show a substantial increase in power factor through the use of a syncronous motor. One test showed an exceptional power factor of 100%. This, as previously stated, was taken with initial crusher only running light, and indicates the possibilities of such a device for correcting a lagging current. When a large number of motors are on the line, this syncronous motor has a much greater job to perform, and as will be noted from the foregoing table makes only a partial correction. Increasing the power factor from 50% to 90% with a 200 K.W. load would require asyncronous motor of about 265 K.V.A. capacity. The present motor is about 100 K.V.A. and while small for a complete correction, it does show considerable improvement, both in the power factor and the generator heating."

"Hot weather, however, may yet show considerable generator temperature, but in view of the possibility of the future use of purchased power, a larger syncronous motor, at this time, is not to be recommended."

By R. B. Ambrose,
Carnegie Institute of Technology.

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QUESTION OF PURCHASED POWER.

On account of the past discouraging results obtained from their own power plant, the management had for some time considered the advisability of purchased power. The nearest central station was about two miles distant, and operated by the Du Bois Electric Co. This power company placed an integrating watt meter on the switch board for ten days and submitted a report. In view of the fact that this company had a rather poor reputation for reliable service, the writer was commissioned to make a study of the problem of purchased power. A report of this was submitted in December 1920, and on March 16, 1921, a conference was called in Du Bois, to consider a proposition of the Brockway Light Heat and Power Co., who proposed to run a high tension line from their plant, a distance of seventy five miles.

There was some legal difficulties in this procedure, but such were not considered impossible. Their rates were better than those of the Du Bois Electric Co., but it was a new organization, and the men in control did not seem to have the proper experience as managers to warrant making a contract at this time.

The Du Bois Electric Co., presented their contract early in February, and on examination the following clause was noted:

QUESTION OF PURCHASED POWER. cont'd.

The Du Bois Electric Co. agrees to refund to the consumer semi-annually for a period of five years, from date of commencing service on J rate, a sum equal to 20% of the amount of each monthly power bill in excess of monthly minimum charge as provided in J rate. In no case shall the total amount of refund exceed the amount of money advanced by the consumer."

The amount to be advanced by the consumer for construction purposes, etc., was $6500.00. This was to be refunded in five years at the rate of 20% of the amount of each monthly power bill in excess of the minimum charge. Without considering interest on the advanced amount, the necessary amount to be refunded each month, in order that the entire amount be returned in five years, would be 6500/60 or $108.00. This is 20% of the monthly current consumption bill, which would make the monthly current bill 5 x 108 = $540.00 at least. Reference to table No. 6 will show the demand or minimum charge to be $456.00 per month, making a total power bill of $996.00 per month.

On account of the difficulties in crushing stone and shipping wet sand in freezing weather, the plant usually operates nine months in the year. The necessary current bill must then be 4/3 x 540 = $720.00 per month. This added to the minimum equals $1176.00 per month for nine months and $456.00 per month for three months as the neceasary minimum amount, for total refund of the $6500.00. It appears that, with normal operation and power always available, the bills would run well over this amount. Failure of power, however, and restricted use of power on acoount of adverse business conditions, through no fault of the consumer, might easily lower the power bills to such an extent as to sacrifice some of the $6500.00 advance. In other words, the contract tied the consumer with a large advance payment, and penalized him for power failure.

The above mentioned clause, and lack of a satisfactory guarantee of uninterrupted power service prevented the purchase of current from this company. Although in the following report submitted

in

QESTION OF PURCHASED POWER. cont'd.

in Dec. 1920, recommendations were made that power be purchased from this company, it was expected that some guarantee of continuous service would be given.

The mill is now operating under its own power, and successfully using the syncronous motor to increase the power factor and lower the generator heating.

The following gives in detail the cost calculations, discussions and recommendations as contained in the writer's original report on the cost of power. This is followed by miscellaneous recommendations concerning recording instruments, centrifugal pump and rope drive. Supplementing the cost report is a sheet showing cost of power as indicated by rates of the Brockway Light, Heat and Power Co, and another sheet showing comparison of power costs, if manufactured or if purchased from the Du Bois or Brockway Companies.

COST OF POWER.

REPORT of Dec. 23, 1921.

"The following is a report covering Power Costs, Water Supply Pumps, Rope Drive and Recording Instruments, the data for which has been gathered from my own tests and from estimates furnished by the Du Bois Electric Co., Renke-Wagner Pump and Supply Co. and the Dodge Engineering Co."

POWER COSTS

"The costs of purchased power as shown in this report has been accurately determined from rates of the Du Bois Electric Co., while that of your manufactures power is necessarily more or less of an approximation. Where accurate data concerning your own costs in lacking, the writer has tried to show average practice and believes that on the whole, a fairly accurate estimate and comparison has been made."

"The power consumption of the entire plant has been taken, in all calculations, by reducing the power output of the Du Bois, Struther Wells and Otto gas engines to the basis of Kilo-watt input, and adding to the Kilo-watt consumption of the remaining part of the plant already electrified. This makes for simplicity and does not materially effect the results."

"In table No. 4 on next page is shown your present power consuming equipment, with rated horse power driving it, proposed size of motors to replace the small gas engines, and the actual power consumption of all units as tested for maximum load."

REPORT of Dec. 23, 1921, cont'd.

TABLE NO. 4

Equipment	Rated H.P. Gas Engines	Rated H.P. Motors.	Actual Kilo-watt consumed.
Belt conveyor		15	9.4
Pumps		75	56.0
Initial crusher		100	46.0
Cross conveyor, wet mill		10	3.6
Cross conveyor, dry mill		10	3.6
Elevator, initial crusher		35	14.4
Wet pan		40	31.0
Wet pan		40	31.0
Screw conveyors		15	8.8
Pebble elevator		10	5.0 estimated
Viabrator		5	5.0 "
Secondary crusher & elevator	125	*70	58.0
Large air compressor	65	*50	34.8
Small air compressor	80	*40	32.4
Dry pan		*25	20.7
Dry pan		*25	20.7
Total connected load		565 H.P.	
Total maximum power consumption, considering complete electrification			378.4 K.W.

*Size of motors required to replace gas engines.

COST OF MANUFACTURED POWER.

LOAD FACTOR.

"The load factor of a power plant is the actual number of Kilo-watt hours consumed per year divided by the rated power consumption of the plant in Kilo-watt hours per year."

"The rated capacity of your plant in Kilo-watt hours per year of 8760 hours is:

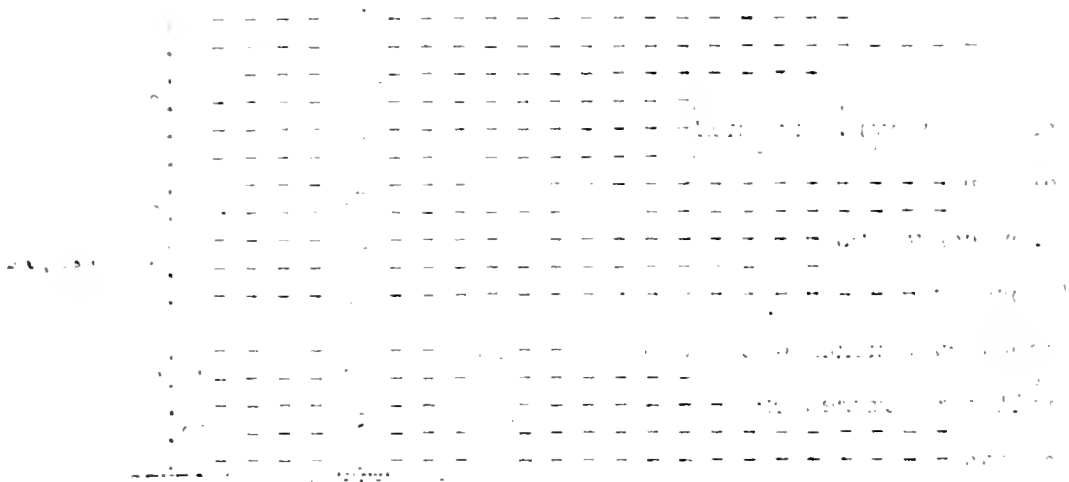
Large generator	210 x 8760	=	1,820,000
Struther Wells	125 H.P.		
Du Bois	80 H.P.		
Otto	65 H.P.		
Total	270 x .746 x 8760	=	1,765,000

Total rated capacity K.W. hours per year = 3,585,000

"In tests made by the Du Bois Electric Co. your plant averaged 1171 K.W. hours in ten hours or 2342 K.W. hours in twenty hours. Working twenty five days per month and nine months per year, your total average K.W. hour consumption per year would be 527,000."

"In tests made by the writer on Dec. 11, it was found that:

Secondary Crusher and elevator required		70 H.P.
Large air compressor	"	42 H.P.
Small air compressor	"	39 H.P.
Dry pan	"	26 H.P.
Dry pan	"	26 H.P.
	Total	203 H.P.



REPORT of Dec. 23, 1921, cont'd.

LOAD FACTOR cont'd

"Considering .9 efficiency of transformation of electrical to mechanical power, this would require about,

$$\frac{203 \times .746}{.9} = 168 \text{ K.W.}$$

Then 168 x 20 x 25 x 9 = 757,000 K.W. hours per year."

"The total K. W. hours per year under present operation, with entire plant electrified, would then be 757,000 plus 527,000 = 1,284,000, and your present load factor would be:"

$$\frac{1,284,000}{3,585,000} = 35.8\%$$

"The power consumption of the dry pans, air compressors and secondary crusher was taken at its maximum. In actual operation this would be reduced and your present load factor would more likely be 30% for 20 hour day and 15% for 10 hour day."

"For greater production it is fair to assume that your yearly consumption of power will greatly increase, and for the purpose of calculating your costs on a simple and practical basis, the writer has taken load factors of 5, 10, 15, 20, 25, 30, 35, 40, and 45% each of which when multiplied by the total yearly rated capacity will give the corresponding yearly power consumption. For comparison then the same yearly power consumptions are shown for calculating cost of power if purchased from the Du Bois Electric Co."

"Power Costs generally fall under two heads, as fixed charges and operating charges. These will be called demand and current charges when power is purchased from the Central Station."

"Table No. 5 shows each cost itemized for the various load factors, for manufactured power."

EXPLANATION OF COST ITEMS, TABLE NO. 5

LOAD FACTOR AND K.W. HOURS PER YEAR.

"Load factors have been considered from 5% to 45%. Your plant is not able to consume more than the power represented by 45 or 50% load factor, except that it works twelve months in the year. This appears to be impracticable, and the cost, therefore, of power for higher load factors is of little importance. Item No. 2 shows the K.W. per hour for 10 hour day, 25 days per month and 9 months per year, necessary to give the K.W. hours per month of item 4 and K.W. hours per year of item 5 for the various load factors shown. Item No. 3 shows in like manner the number of K.W. hours per year for 10 hour day."

FIXED CHARGES - INTEREST.

"According to information given by your Mr. Nichols, your present power generating equipment, exclusive of motors and any mill equipment, and including 4 gas engines, 2 generators, switch board and accessory equipment, represents an outlay of approximately $16000.00. The interest charge is taken as 6% of this amount."

REPORT of Dec. 23, 1921, cont'd.

FIXED CHARGES, cont'd.

DEPRECIATION.

"Depreciation is very difficult to determine; first, because it is more or less problematical just how lond an engine will last, and second, on account of the increasing scarcity and price of gas, gas engines in this territory are fast becoming obsolete. The engine might be in good condition at the end of ten years but practically worthless on account of the gas situation. Considering a reasonably favorable gas price and good engine attention, it is fair to assume that the engines will have a life of ten years more. This has been used as the basis of the depreciation charge and inorder to simplify the matter, they have been considered to be worthless at that time. 8.33% of the first cost ($16000.00) set aside at 4% will equal the first cost in ten years. This is a rather heavy depreciation charge and its error is in favor of the central station. This should be kept in mind when final comparison is made."

INSURANCE AND TAXES.

"In the absence of actual figures on insurance and taxes, the writer has taken a flat 2% of the initial cost of the power plant equipment. This represents average plant practice covering fire and safty insurance, and possible taxes. This item is small compared with the total power cost, and considerable error would be of minor consequence."

MASTER MECHANIC AND SUPERINTENDENCE.

"$1200.00 per year of the master mechanic's time and $800.00 per year of the superintendence time has been charges to the power costs as a fixed charge."

TOTAL FIXED CHARGE.

"The total annual fixed charge is the sum of the interest, depreciation, insurance and supervision and remains constant for any load or any load factor."

FIXED CHARGE PER K.W. HOUR.

"Since the fixed charge remains constant and the K.W. hr. consumption increases with increase in load factor, the cost per K. W. hr. decreases with increase in load factor."

OPERATING CHARGES - GAS.

"By checking your monthly gas consumption against the probable average monyhly K.W. hr. consumption, it was found that you were 20-25 cu. ft. of gas per K.W. hr. In calculating the gas consumption for various K.W. hr. consumption, 25 cu. ft. per K.W. hr. was used for 5 and 10% load factor, 20 cu. ft. for 15-20-25% load factor, and 18 cu. ft. for 35-40-45% load factor. This is a fair charge because all gas engines will use less gas per unit of power, for full load than for light load. All gas is figured on a nine month year basis, for both 50 and 60 cent gas."

LABOR AND ATTENDANCE.

"For ten hour day operation you require two engineers at atotal sum of $3600.00 per year. For twenty hour day operation you require four engineers at a total sum of $7200.00 per year. Working ten hours per day the maximum load factor will lie between 20 and 25%, hence the change from $3600.00 to $7200.00 per year for labor and attendance at these load factors."

Cost of Manufactured Power - Falls Creek Sand and Stone Co.

Table No. 5

1	Load Factor %	5	10	15	20	25	30	35	40	45
2	K.W. per hour, 10 hour day	88.4	159.6	239.0	318.0	398.0	478.0			
3	K.W. per hour, 20 hour day	44.2	79.6	119.5	159.0	199.0	239.0	279.0	319.0	358.0
4	K.W. hours per month	22100	39900	59900	79600	99600	119500	139800	159600	179000
5	K.W. hours per year	199000	358000	538000	717000	896000	1075000	1258000	1436000	1610000
6	Rated K.W. hrs. per year = 3,585,000									
	Fixed Charges									
7.	Interest on $16000.00 @ 6%	$960.00	960.00	960.00	960.00	960.00	960.00	960.00	960.00	960.00
8.	Depreciation - 8.33%	1300.00	1300.00	1300.00	1300.00	1300.00	1300.00	1300.00	1300.00	1300.00
9.	Insurance and Taxes	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00
10.	Master Mechanic and Superintendence	2000.00	2000.00	2000.00	2000.00	2000.00	2000.00	2000.00	2000.00	2000.00
11.	Total Fixed Charges per year	4580.00	4580.00	4580.00	4580.00	4580.00	4580.00	4580.00	4580.00	4580.00
12.	Fixed Charges per K.W. hr. cents	2.32	1.28	.65	.64	.51	.43	.37	.32	.29
	Operating Charges									
13.	Gas per year - @ 60¢ per 1000 cu. ft.	$2460.00	4910.00	5940.00	7880.00	9850.00	11780.00	12420.00	14200.00	15950.00
14.	Gas per year - @ 50¢ per 1000 cu. ft.	2240.00	4470.00	5400.00	7170.00	8960.00	10750.00	11300.00	12900.00	14500.00
15.	2-Engineers, per yr, 10 hour day	3600.00	3600.00	3600.00	3600.00	3600.00	3600.00			
16.	4 Engineers, per yr, 20 hour day				7200.00	7200.00	7200.00	7200.00	7200.00	7200.00
17.	Oil and Waste, per yr.	1000.00	1150.00	1200.00	1250.00	1300.00	1350.00	1400.00	1450.00	1500.00
18.	Repairs and Maintenance	1000.00	1000.00	1200.00	1500.00	1800.00	2000.00	2500.00	3000.00	3500.00
19.	Total Op. Costs, per yr., 10 hr. day, 60¢ gas	8060.00	10660.00	11940.00	14230.00	16550.00	18730.00			
20.	Total Op. Costs, per yr., 20 hr. day, 60¢ gas				17830.00	20150.00	22330.00	23520.00	25850.00	28150.00
21.	Total Op. Costs, per yr., 10 hr. day, 50¢ gas	7840.00	10220.00	11400.00	13520.00	15660.00	17700.00			
22.	Total Op. Costs, per yr., 20 hr. day, 50¢ gas				17120.00	19260.00	21300.00	22400.00	24550.00	26700.00
23.	Op. Costs, Cents, K.W. hr. 10 hr. day, 60¢ gas	4.05	2.98	2.22	1.99	1.85	1.74			
24.	Op. Costs, Cents, K.W. hr. 20 hr. day 60¢ gas				2.49	2.25	2.08	1.87	1.80	1.76
25.	Op. Costs, Cents, K.W. hr. 10 hr. day 50¢ gas	3.94	2.86	2.16	1.88	1.75	1.65			
26.	Op. Costs, Cents, K.W. hr. 20 hr. day 50¢ gas				2.39	2.15	1.98	1.78	1.71	1.66
27.	Fixed Charges Cents, K.W. hr.	2.32	1.28	.65	.64	.51	.43	.37	.32	.29
	Total Net Cost Cents, - K.W. Hr.									
28.	Total Net Cost K.W. hr. 10 hr. day 60¢ gas	6.37	4.26	3.07	2.63	2.36	2.17			
29	" " " " " 20 " " " "				3.13	2.76	2.51	2.24	2.12	2.04
30	" " " " " 10 " " 50¢ gas	6.26	4.14	3.01	2.52	2.26	2.08			
31	" " " " " 20 " " " " "				3.03	2.66	2.41	2.15	2.03	1.95

REPORT OF DEC. 23, 1921, cont'd.

OPERATING CHARGES. cont'd.

OIL AND WASTE.

"Your estimate gives an average of $1200.00 per year for oil, waste and supplies for power plant use. I have varied this charge from $1000.00 at 5% load factor to $1500.00 at 45% load factor. Such charges will naturally increase slightly as the power consumption increases."

REPAIRS AND MAINTENANCE.

"Your estimate of repairs and maintenance gives $1200.00 per year as a fair average. I have varied this charge from $1000.00 per year at 5% load factor to $3500.00 per year at 45% load factor. This charge will tend to increase rapidly under stress of heavy loads."

TOTAL OPERATING CHARGE.

"The total operating charge is the sum of the labor & attendance, oil & waste, and repairs & maintenance. This increases with the increase in load factor and power consumption, but at a less rate. The operating charges, therefore, per K.W. hr. become less as the power consumption increases."

TOTAL COST OF POWER. CENTS PER K.W. HR.

"The total net cost of your power in cents per K.W. hr. is the sum of the fixed charge per K.W. hr. and the operating charge per K.W. hr. This varies, as shown in Table No. 5, from 6.37 to 2.04 cents per K.W. hr. for sixty cent gas, and from 6.26 to 1.95 cents per K.W. hr. for fifty cent gas."

COST OF POWER, IF PURCHASED FROM THE DU BOIS ELECTRIC CO.

RATES.

"The rates of the Du Bois Electric Co., according to their large power rate "J" are as follows:

TABLE NO. 6.

Demand charge:

$2.00	per	month	per	K.W.	for	first	200	K.W.	of	demand.
1.75	"	"	"	"	"	next	200	"	"	"
1.50	"	"	"	"	"	"	200	"	"	"
1.25	"	"	"	"	all	over	600	"	"	"

Energy charge for all power used:

2.25	cents	per	K.W.	hour	for	the	first	5000	K.W.	hrs.	per month.
1.75	"	"	"	"	"	"	next	10000	"	"	"
1.50	"	"	"	"	"	"	"	25000	"	"	"
1.25	"	"	"	"	"	all	over	40000	"	"	"

Discount: A discount of 5% will be allowed on all bills paid before the 10th of the month following that in which service is rendered.

Surcharge: Additional charge of 15% to the gross bill on all bills rendered. This was explained as a war surcharge originally and retained at present time on account of high price of coal."

COST OF POWER, IF PURCHASED FROM THE DU BOIS ELECTRIC CO. cont'd.

DEMAND CHARGE.

"The demand charge is based upon 55% of the rated capacity of all motors connected to the line. In calculating this demand, as shown on table No. 7, the Du Bois, Struther Wells and Otto gas engines were considered as being replaced by 210 H.P. of motors, making a total plant motor load of 565 H.P. as indicated on Table No. 4. Then, 565 x .746 x .55 = 252 K.W. demand."

CURRENT CHARGE.

"In calculating this current charge, amounts of yearly current consumption were used corresponding to the 5-10-15-20-25-30-35-40-45% load factors of the present plant. Tha charges of each amount of current consumption has been carried through according to the company's rates, on a monthly basis (items 2 to 6, Table No. 7.) and then transferred to a yearly basis (items 7 to 10, Table No. 7.), and to cents per K.W. hr. (items 11 to 15). The net charge of the Du Bois Electric Co., is shown in item 13, Table No. 7. To this charge has been added the fixed charge of the present plant as shown in items 14 and 15. It is assumed that the present plant will be kept as an insurance against shut down by the Du Bois Electric Co., and as such its fixed charges will remain practically the same as though it were in operation."

POWER COSTS SHOWN GRAPHICALLY.

On the curve sheet No. 1 are four curves showing relation of load factor or power consumption, and cost per K.W. hour. No. 1 curve shows cents per K.W. hour for present plant operating ten hours per day. This curve ends at 25% load factor because greater consumption than 478 K.W. per hour is not probable, and will usually average considerable less. Probable average is shown at 15% load factor, 239 K.W. per hour, and 338000 K.W. hours per year. No. 2 curve shows cents per K.W. hr. for present plant operating 20 hrs. per day. This curve starts at 20% load factor and extends to 45% with a probable average at 30%, or with a yearly consumption of 1,075,000 K.W. hrs. With improved plant production greater than this amount should be expected, but it is not likely that it will ever reach the maximum of 45%. This would require every motor to operate at full load continuously 20 hours per day, 25 days per month, and 9 months per year. No. 3 curve shows the costs for the same power consumption, according to rates of the Du Bois Electric Co., and on curve No. 4 are these same costs to which has been added the fixed charges of the present plant.

The results of these cost calculations, shown on the curve sheet, point out the following:

1. The Du Bois Electric Co's charges alone, show less cost than your plant for all 20 hour day operation where four engineers are required.

2. The Du Bois Electric Co's charges alone, show less cost than your plant for all 10 hour day operation with two engineers, except above 22% load factor.

3. When the fixed charges of the present plant are added to the Du Bois Electric Co's costs, the latter shows quite a little higher for ten hour day operation, and a maximum of 1/4 cent per K.W. hour more for twenty hour day operation.

4. 20-hour-day is the most economical, while 10-hour-day is wastful and almost prohibitive for purchased power, with present plant used as insurance against power failure.

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TRBLE No 7

DEMAND CHARGE BASED ON TOTAL ELECTRIFICATION

365 X .746 = 422. K.W.
425 X .55 = 232 K.W. Demand

Demand charge is equal to

$2.00 per Mo. for 1st 200 K.W. = $400.00
1.75 " " " 32 K.W. = 56.00
Total demand = $456.00 per Mo.
Total yearly demand $456. X 12 = $5470.00

OPERATING BASED ON CURRENT USED TOTAL ELECTRIFICATION

1	K.W. per Month	27100	39900	59900	79600	99600	119500	139800	159600	179000
2	1st 5000 @ 2.25¢	$112.50	112.30	112.50	112.50	112.50	112.50	112.50	112.50	112.50
3	Next 10000 @ 1.75¢	$175.00	175.00	175.00	175.00	175.00	175.00	175.00	175.00	175.00
4	Next 25000 @ 1.50¢	$106.00	374.00	375.00	375.00	375.00	375.00	375.00	375.00	375.00
5	Above 40000 @ 1.25¢			249.00	495.00	745.00	993.00	1245.00	1495.00	1740.00
6	Total Current Charges per Mo.	$393.50	661.50	911.50	1157.50	1407.50	1655.50	1907.50	2157.50	2402.50
7	Total Current Charges per yr-9 Mo	$3540.00	5950.00	8200.00	10400.00	12600.00	14900.00	17200.00	19400.00	21700.00
8	Demand Charges per yr.	$5470.00	5470.00	5470.00	5470.00	5470.00	5470.00	5470.00	5470.00	5470.00
9	Total Charges Power per yr.	$9010.00	11420.00	13670.00	15870.00	18070.00	20370.00	22670.00	24870.00	27170.00
10	K.W. Hours per yr.	199000	358000	538000	717000	896000	1075000	1258000	1436000	1610000
11	Cost per K.W. Hr, Cents	4.53	3.19	2.54	2.20	2.01	1.89	1.80	1.73	1.69
12	Plus 15% Sur. Charge Cents	5.2	3.67	2.92	2.53	2.31	2.17	2.07	1.99	1.95
13	Less 5% For Cash	4.94	3.48	2.77	2.4	2.19	2.06	1.97	1.89	1.85
14	Present Fixed Charges per K.W. Hr. Cents	2.56	1.28	.85	.64	.51	.43	.37	.32	.29
15	Total Net Cost per K.W. Hr. Cents	7.50	4.76	3.62	3.04	2.70	2.49	2.34	2.21	2.14

REPORT OF DEC. 23, 1921, cont'd.

RECOMMENDATIONS. POWER.

The following recommendations are made in consideration of the foregoing, and of the necessity for reliable power service:

1. That power be purchased for the entire plant as soon as arrangements can be made with the Du Bois Electric Co., for ample and reliable service of current at or less than the figure quoted in this report.

2. That steps be taken at an early date for electricication of secondary crusher and elevator, both compressors and both dry pans, as per sizes shown in Table No. 4.

3. That present plant be kept in tact, as additional power insurance until the Du Bois Electric Co., has demonstrated its ability to give uninterrupted service.

4. That plant be operated as at present until such a time as as the Du Bois Electric Co. can furnish reliable power for the entire plant.

At first thought it seemed that it might be advisable to electrify the present load of the Du Bois, Struther Wells and Otto gas engines, and buy enough power to drive the initial crusher, secondary crusher and air compressor, carrying the dry pans and remainder of the plant on the large generator. This would relieve the present generator from large fluctuating crusher loads, but on account of large demand and high prices for current in small quantities, your power bill would increase by about $800.00 to $1200.00 per month, and decrease $300.00 per month by relief of two engineers. Your are after reliability, and your past experience does not indicate that the Du Bois Electric Co. can give much of a guarantee for reliable service at this time. In other words the cost is too high for a small amount or possibly no additional reliability.

RECORDING INSTRUMENTS.

One of the best ways of remedying past troubles and avoiding new ones, is to keep an accurate record of the important phases of of operation, and particularly of all troubles. That is, a log sheet should be kept, showing the time that all motors are in service, and the time they are shut down. When ever a break occurs, it should be noted on the log and a description given. A recording watt meter would show you as a check on the motor logs, the exact amount of power use at any time during the priod of operation. If no satisfactory arrangement can be made with the Du Bois Electric Co., for power, and the present plant should continue in operation, you would need in addition to the watt meter, a recording and indicating power factor meter. If the Electric Co. would give any concession for high power factor, such a meter would be advisable for purchased power.

The recording watt meter will be valuable, whether you make or buy your power, and I would recommend the purchase of an Esterline Graphic Recording Watt Meter for 200 volts and 500 K.W. The instrument will cost $225.00 less 10%, and will give a complete and continuous record of your power consumption for one week without renewal of paper. This instrument can be purchased from the Esterline Co., First National Bank Bldg., Pittsburgh, Pa., and will require four to six weeks for delivery.

REPORT OF DEC. 23, 1921, cont'd.

RECOMMENDATIONS. PUMPS.

"A letter to you from the Reineke-Wagner Pump and Supply Co., Pittsburgh, Pa., states that they have the following direct connected pumps, suitable for duty in your pump house:

1 - 5" two stage	75 H.P.	500 gallons per minute.
1 - 6" two stage	100 H.P.	900 gallons per minute.

The curves of performance of these pumps, submitted to you show that the 5" pump requires 60 H.P. when delivering 500 gallons per minute at 300 foot head, and the 6" pumprequires 98 H.P. when delivering 900 gallons per minute at 300 foot head. Apparantly, from the nominal rating of the motors and pumps, you gain 400 gallons per minute for an expenditure of 25 H.P. in the larger pump. Actually you get it at an expenditure of 38 H.P. The larger pump is a little more efficient, but if you used this to supply all of your water, there would be 400 to 500 gallons per minute pumped to high pressure and used at a low pressure. This inefficient method would offset the gain secured in using the larger and more efficient pump."

"Your wet mill requires about 500 gallons per minute of high pressure water, and about the same amount of low pressure water. Your present triplex pump is sufficiently large to take care of the high pressure water and the centrifugal pump easily handles the remaining supply. There has been some difficulties however in operating these pumps continuously, particularly with regard to the triplex pump. It is recommended therefore, that if a centrifugal pump is installed to insure your water supply, it be belted to a line shaft operated by the present 75 H.P. motor. All three pumps then should be connected to this motor is such a manner that the low pressure centrifugal pump can be operated with either triplex, or high pressure centrifugal pump."

"It requires less than 60 H.P. to furnish your present water supply, and any grouping of motors, that aggregate more than 75 H.P. would be inefficient. Installation of a 75 H.P. direct connected unit, would necessitate the purchase of a 15 H.P. motor for the low pressure centrifugal pump, so that it could be operated independent of either high pressure pump. This would lighten the present 75 H.P. Motor to a disadvantage. Grouping the three pumps on the present motor therefore seems to give the best loading condition, and the most efficient motor operation."

ROPE DRIVE TO INITIAL CRUSHER.

"Estimates of the Dodge Sales and Engineering Co., quote $1208.96 for one endless rope drive, with weight tightener, carriage track and various accessories. This is exclusive of labor."

"They also quote $600.00 for four separate strands of cotton rope to replace the present hemp rope. This rope is imported and costly in replacements, and in neither case will they give any guarantee as to the life of the rope."

"Your present belt from motor to the line shaft shows many times greater life than the rope to the crusher. There is no doubt that the rope receives the greater shocks and its life is shortened thereby, but information from the Dodge Co., indicates a very serious doubt as to the ability of a rope drive to give the desired service in this place."

REPORT OF DEC. 23, 1921. cont'd.

RECOMMENDATIONS, ROPE DRIVE, cont'd.

"For successful rope drive, if such were possible in this particular service, your pulleys would have to be larger for 2" rope or else wider and more strands of 1 1/2" rope. You would need the American or continuous rope system, which considering labor of installing would be quite expensive, and in the end would carry no guarantee."

"In view of the facts stated, the belt drive is to be recommended as offering the best solution for frequent break downs of your transmission to the initial crusher."

By, R. B. Ambrose,
Carnegie Institute of Technology.

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SUPPLEMENT TO POWER COST REPORT OF DEC. 23.

PROPOSITION OF THE BROCKWAY LIGHT, HEAT AND POWER CO.

The proposal of the Brockway Light, Heat and Power Co., has been mentioned on page 11, but, since this matter did not come up until March 6, it was not incorporated in the original report of Dec. 23.

The rates of this company are shown in Table No. 8, and the detailed cost calculations are shown in Table No. 9. In Table No. 10 are shown the comparative costs of manufactured power, purchased power from Du Bois Electric Co., and purchased power from the Brockway Light Heat and Power Co. These latter comparisons are also shown graphically on Curve Sheet No. 2.

RATES OF THE BROCKWAY LIGHT, HEAT AND POWER CO.

TABLE NO. 8

DEMAND CHARGE

$2.50	per	month	for	first	15	K.W.	of demand.
2.00	"	"	"	next	25	"	" "
1.75	"	"	"	"	60	"	" "
1.55	"	"	"	all over	100	"	" "

ENERGY CHARGE FOR ALL POWER USED.

4.0	cents	per	K.W.	hr.	for	the	first	500	K.W.	hrs.	per	month.
3.5	"	"	"	"	"	"	next	1000	"	"	"	"
3.0	"	"	"	"	"	"	"	2000	"	"	"	"
2.0	"	"	"	"	"	"	"	3000	"	"	"	"
1.75	"	"	"	"	"	"	"	4000	"	"	"	"
1.5	"	"	"	"	"	"	"	50000	"	"	"	"
1.25	"	"	"	"	"	all over		60500	"	"	"	"

DISCOUNT: A discount of 5% will be allowed on all bills paid before the 10th of the month following that in which service is rendered.

DEMAND CHARGE.

The damand charge shown in Table No. 9 is based upon 55% of the rated capacity of all motors. In figuring this charge the Du Bois, Struther Wells and Otto gas engines are considered as replaced by 210 H.P. of motors as shown in Table No. 4, making a total motor load of 565 H.P. Then, 565 x .746 x .55 = 232 K.W. demand. This is the same calculation as used in determining the Du Bois Electric Co's costs, as shown on page 18.

CURRENT CHARGE.

In calculating the current charge, the same method was also used as indicated on page 18, for the Du Bois Electric Co. In table No. 9 are shown the current charges and total cost per K.W. hr. if power is purchased from the Brockway Light, Heat and Power Co.

De

565 x

Dem

2.50

2.00

1.75

1.55

Tota

Op

1	K.W.
2	1st
3	Next
4	"
5	"
6	"
7	"
8	All o
9	Total
10	Total
11	Demo
12	Total
13	K.W. h
14	Cents
15	Less

Load fac
K.W. per

Own Pl
50 C

60 C

Du Bois
of pre

Brock N
of pre

TABLE 9

BROCKWAY ELECTRIC CO. SUPPLEMENT TO REPORT OF DEC 23

DEMAND CHARGE BASED ON TOTAL ELECTRIFICATION

565 X .746 X .55 = 232 K.W. Demand

Demand charge is equal to 1

$2.50	per K.W. per mo. for 1st 15 K.W.	=	$37.50
2.00	per K.W. per mo. for next 25 K.W.	=	50.00
1.75	per K.W. per mo. for " 60 K.W.	=	105.00
1.35	per K.W. per mo. for 132 K.W.	=	204.60
	Total Demand	=	397.10

Total yearly Demand = 397.10 X 12 = $4765.20

OPERATING CHARGES BASED ON CURRENT USED TOTAL ELECTRIFICATION

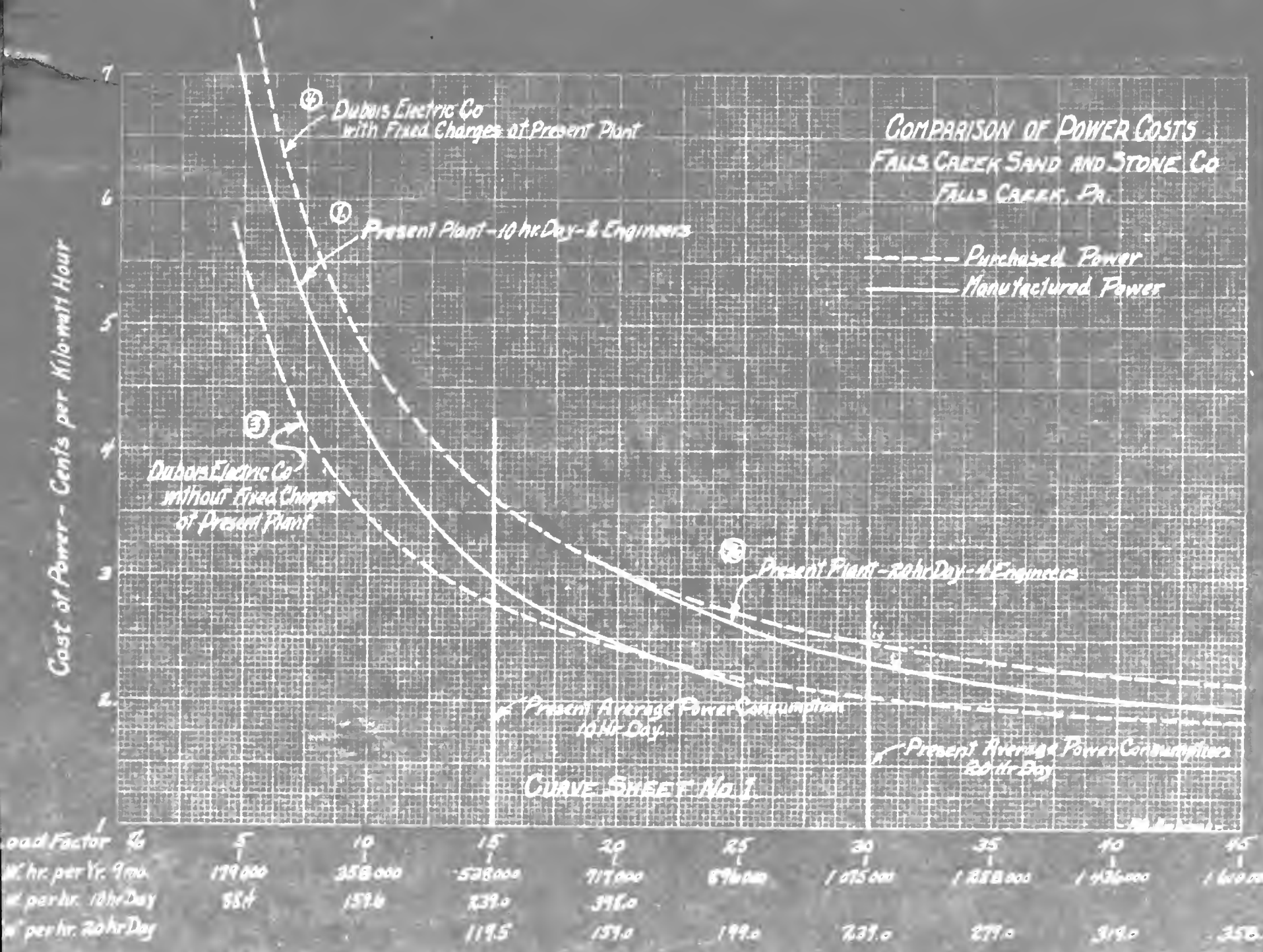
1	K.W. per Mo.	22,100	39900	59900	79600	99600	119500	139600	159600	179000
2	1st 500 @ 4¢	$20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
3	Next 1000 @ 3.5¢	$35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
4	" 2000 @ 3¢	$60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
5	" 3000 @ 2¢	$60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
6	" 4000 @ 1.75¢	$70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
7	" 5000 @ 1.5¢	$174.00	441.00	741.00	750.00	750.00	750.00	750.00	750.00	750.00
8	All above @ 1.25¢				239.00	488.00	737.00	990.00	1240.00	1481.00
9	Total Current Charge	$419.00	686.00	986.00	1234.00	1483.00	1732.00	1985.00	2235.00	2476.00
10	Total Current Chg per yr-9Mo.	$3770.00	6180.00	8890.00	11110.00	13380.00	15610.00	17890.00	20120.00	22250.00
11	Demand per yr 12. Mo.	$4765.00	4765.00	4765.00	4765.00	4765.00	4765.00	4765.00	4765.00	4765.00
12	Total Chg Power per. year	$8535.00	10945.00	13655.00	16875.00	18145.00	20375.00	22655.00	24885.00	27015.00
13	K.W. hrs. per yr. 9-Mo.	199000	358000	538000	717000	896000	1075000	1258000	1436000	1615000
14	Cents per K.W. hrs	4.28	3.05	2.53	2.21	2.02	1.89	1.8	1.73	1.67
15	Less 5% for Cash, Cents K.W.hr	4.07	2.90	2.4	2.10	1.92	1.80	1.71	1.64	1.59

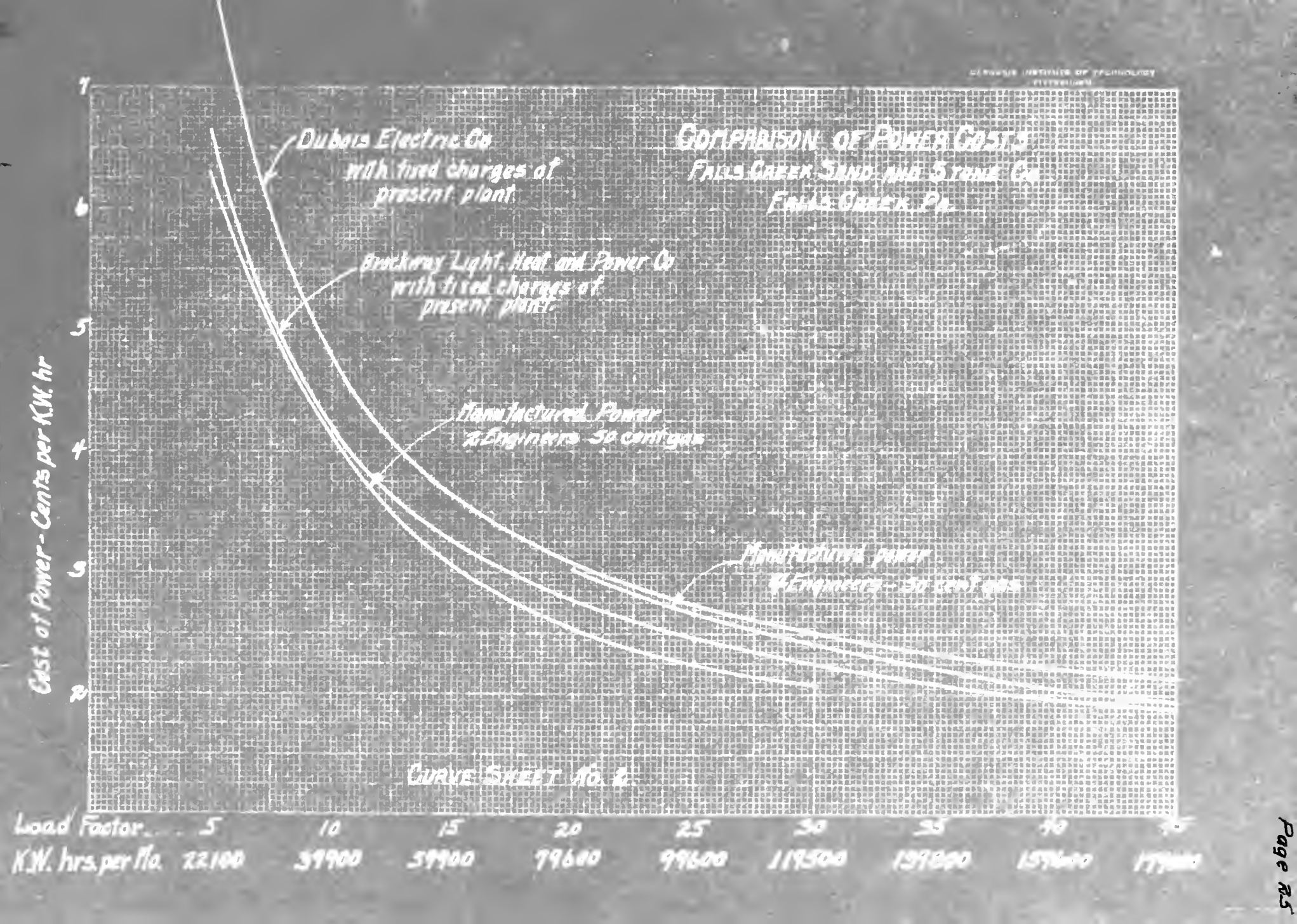
TABLE 10

COMPARATIVE ESTIMATE OF POWER COST AT PLANT OF FALLS CREEK SAND AND STONE CO.

Load Factor K.W. per Mo.	5% 22100	10% 39900	15% 59900	20% 79600	25% 99600	30% 119500	35% 139600	40% 159600	45% 179000
OWN PLANT - Cents per K.W. Hr									
50 Cent Coal									
2-Engineers	6.26	4.14	3.01	2.52	2.26	2.08			
4-Engineers				3.07	2.66	2.41	2.18	2.03	1.93
60 Cent Coal									
2-Engineers	6.37	4.26	3.07	2.63	2.36	2.17			
4-Engineers				3.13	2.76	2.51	2.24	2.12	2.04
Du Bois Elec Co. With fixed charges at present plant, Cents per K.W.Hr	8.06	4.76	3.62	3.04	2.70	2.40	2.34	2.21	2.14
Brockway Elec Co. With fixed charges at present plant, cents per K.W.Hr	6.63	4.18	3.25	2.74	2.43	2.25	2.08	1.95	1.88

Note:- The Du Bois Elec. Costs were calculated including the 15% surcharge, and 5% cash discount while that of the Brockway Elec Co, has no surcharge, but the above figures include the 5% Cash Discount.


COMPARISON OF POWER COSTS
FALLS CREEK SAND AND STONE CO
FALLS CREEK, PA.
Purchased Power
Manufactured Power
Cost of Power - Cents per Kilowatt Hour
Dubois Electric Co with Fixed Charges of Present Plant
Present Plant - 10 hr Day - 4 Engineers
Dubois Electric Co without Fixed Charges of Present Plant
Present Plant - 20 hr Day - 4 Engineers
Present Average Power Consumption 10 Hr Day
Present Average Power Consumption 20 hr Day
CURVE SHEET - No. 1
7
6
5
4
3
2
1
Load Factor %
5
10
15
20
25
30
35
40
45
K.W. hr. per Yr. 9 mo.
199 000
358 000
538 000
717 000
896 000
1 075 000
1 254 000
1 436 000
1 619 000
¢ per hr. 10 hr Day
55.4
159.6
239.0
396.0
¢ per hr. 20 hr Day
119.5
159.0
199.0
239.0
279.0
319.0
358.0


COMPARISON OF POWER COSTS
FALLS CREEK SAND AND STONE CO
FALLS CREEK PA.
Dubois Electric Co
with fixed charges of
present plant
Brockway Light, Heat and Power Co
with fixed charges of
present plant
Manufactured Power
Engineers Specifications
Manufactured Power
Engineers Specifications
CURVE SHEET NO. 2
Cost of Power - Cents per K.W. hr
7
6
5
4
3
2
Load Factor 5 10 15 20 25 30 35 40
K.W. hrs. per Mo. 22100 39900 59900 79600 99600 119500 139600 159600

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